RIPTIDE: a novel recoil-proton track imaging detector for fast neutrons

A. Musumarra[1,2], F. Leone[1,2], C. Massimi[5,3,4], M.G. Pellegriti[2], F. Romano[2], R. Spighi[4] and M. Villa[3,4]

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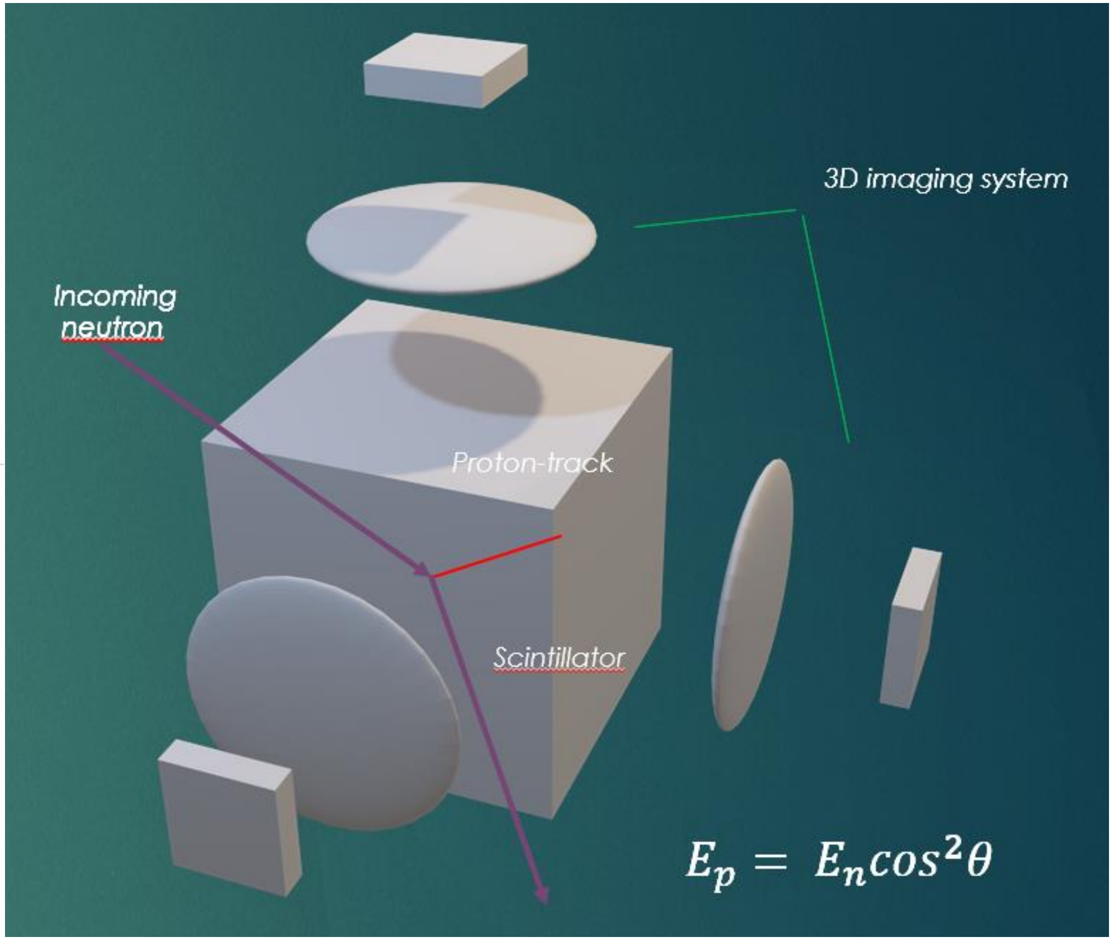

Journal of Instrumentation

PAPER

"RIPTIDE" — an innovative recoil-proton track imaging detector

C. Massimi[1,2], A. Musumarra[4,3,2], F. Leone[3,2], M.G. Pellegriti[2], F. Romano[2], R. Spighi[2] and M. Villa[1,2]

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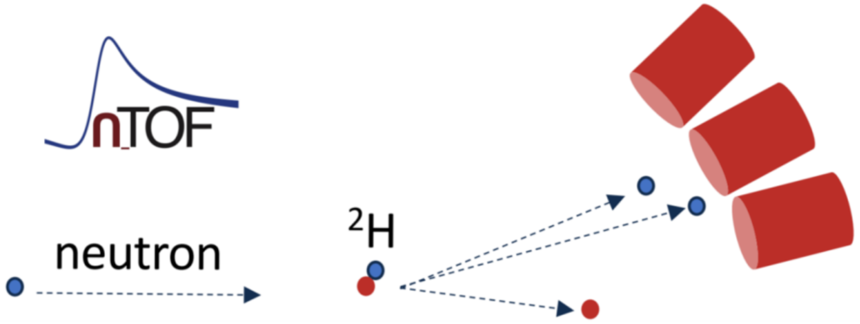
Citation C. Massimi *et al* 2022 *JINST* **17** C09026

Article PDF

Why a recoil-proton detector ?



- *Nuclear Physics (e.g. n-n@n_TOF)*
- *n-dosimetry (n-source localization and imaging)*
- *Astrophysics (n-detection in space environment)*

perform *n*-tracking (*n*-momentum reconstruction)
boosting detection efficiency

A way to go: embedding converter and detector

The basic approach:

SCIENTIFIC REPORTS

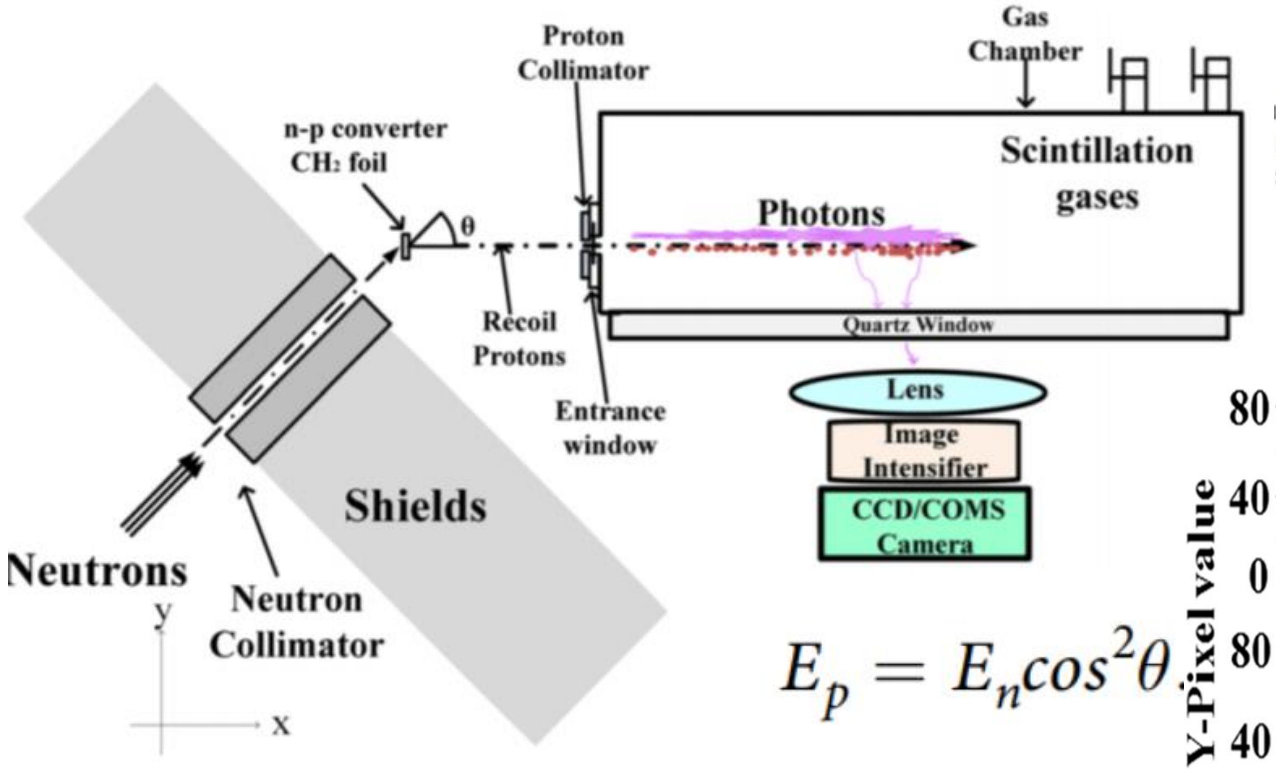
OPEN

Recoil-proton track imaging as a new way for neutron spectrometry measurements

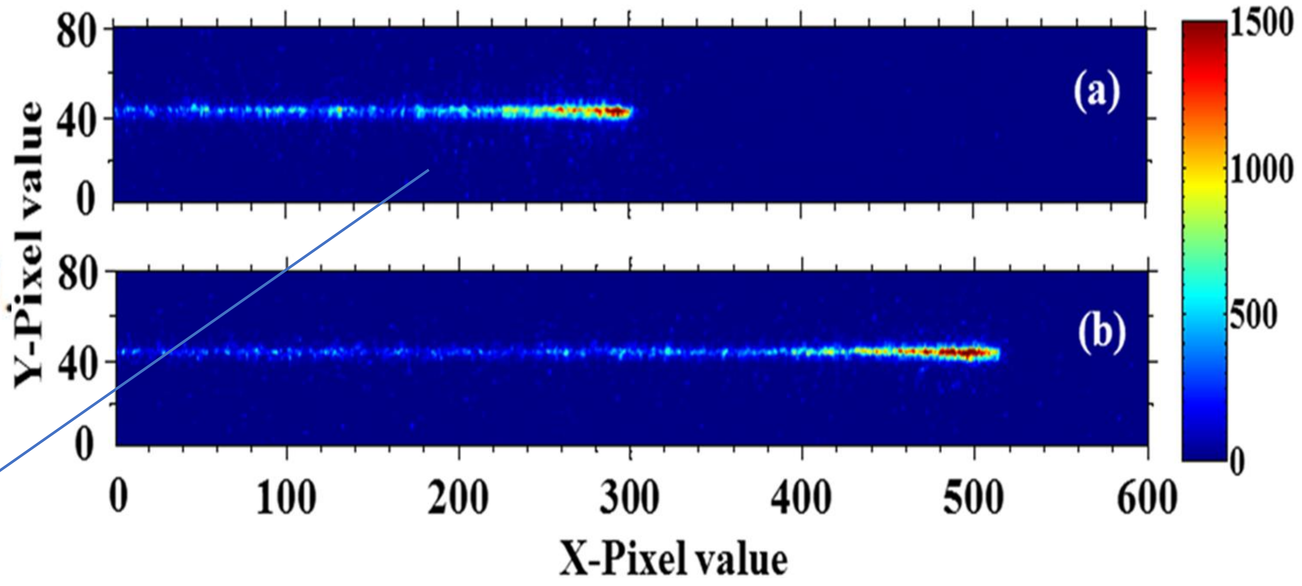
Jing Hu[1,2], Jinliang Liu[2], Zhongbing Zhang[2], Liang Chen[2], Yuhang Guo[3], Shiyi He[1,2], Mengxuan Xu[2,3], Leidang Zhou[2,3], Zhiming Yao[2], Xingqiu Yuan[4], Qingmin Zhang[3] & Xiaoping Ouyang[1,2]

18
2018
September 2018

Sci. Rep. 8, 13363 (2018)



$$E_p = E_n cos^2\theta$$



range → energy

Increasing detection efficiency by detecting multiple scattering in plastic scintillators fibers

ELSEVIER

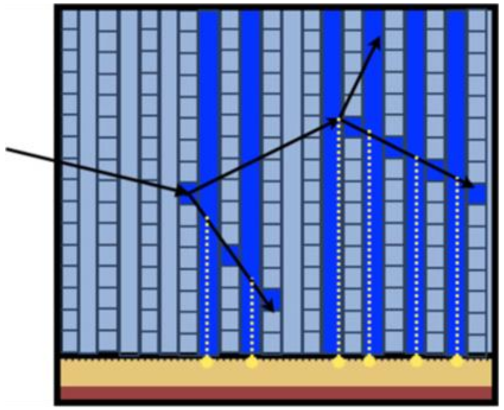
Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment

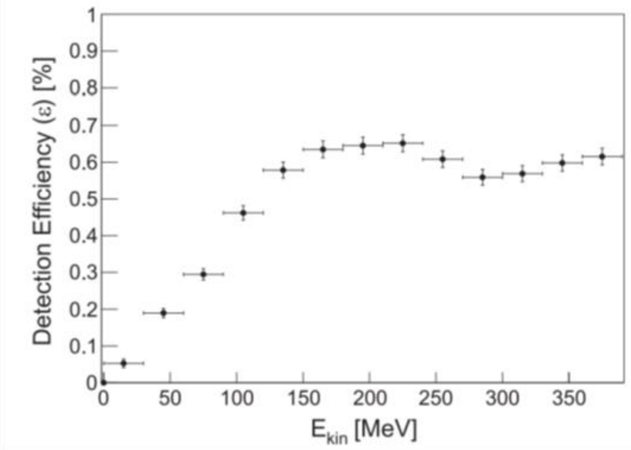
Volume 845, 11 February 2017, Pages 556-559

The MONDO project: A secondary neutron tracker detector for particle therapy

S.M. Valle [a, b], G. Battistoni [a], V. Patera [c, d, e], D. Pinci [c], A. Sarti [d, e, f], A. Sciubba [c, d, e], E. Spiriti [f], M. Marafini [c, d]

"The neutron tracking principle is based on the reconstruction of **two consequent elastic scattering interactions of a neutron with a target material**. Reconstructing the recoiling protons it is hence possible to measure the energy and incoming direction of the neutron".





PROCEEDINGS OF SCIENCE

ONLINE ICRC 2021 THE ASTROPARTICLE PHYSICS CONFERENCE Berlin | Germany 37th International Cosmic Ray Conference 12–23 July 2021

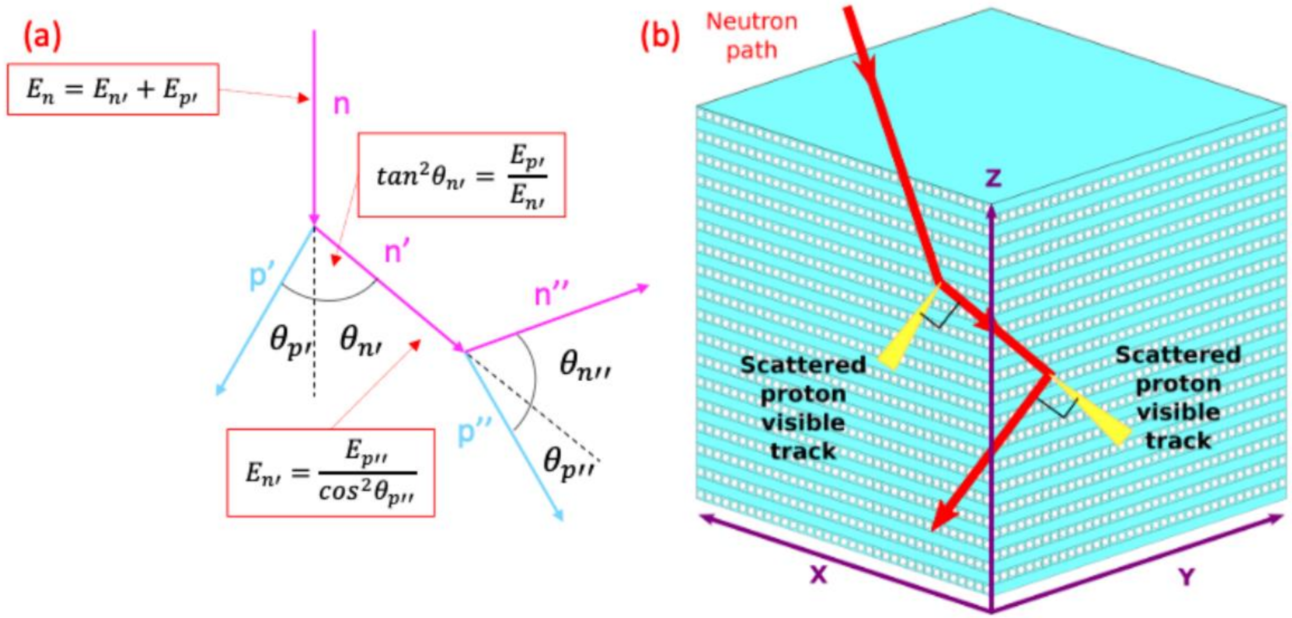
Development of the Solar Neutron TRACking (SONTRAC) Concept

J. G. Mitchell,[a,b,*] G. A. de Nolfo,[b] A. Bruno,[c,b] J. Dumonthier,[b] I. Liceaga-Indart,[b,c] J. Link,[d,b,†] J. Legere,[d] R. Messner,[e] J. Ryan,[d] G. Suarez[b] and T. Tatoli[c,b]

[a] *Department of Physics, George Washington University, Washington, DC, USA*
[b] *NASA Goddard Space Flight Center, Greenbelt, MD, USA*
[c] *Catholic University, Washington, DC, USA*
[d] *University of Maryland, Baltimore County, Baltimore, MD, USA*
[d] *Space Science Center, University of New Hampshire, Durham, NH, USA*
[e] *ECE Department, College of Engineering and Physical Science, University of New Hampshire, Durham, NH, USA*
[†] *No longer affiliated with NASA or CRESST as of May 2021*

The SONTRAC Concept

The SONTRAC detector can unambiguously reproduce the energy and direction of each incident neutron. The approach is based on the non-relativistic elastic double scatter of neutrons off ambient hydrogen. SONTRAC is based on an earlier concept investigated at Case Western Reserve University (Frye et al. 1985, 1987; Pendleton et al. 1988) and developed, to the level of a small prototype, with NASA Supporting Research & Technology (SR&T) funds by the University of New Hampshire.

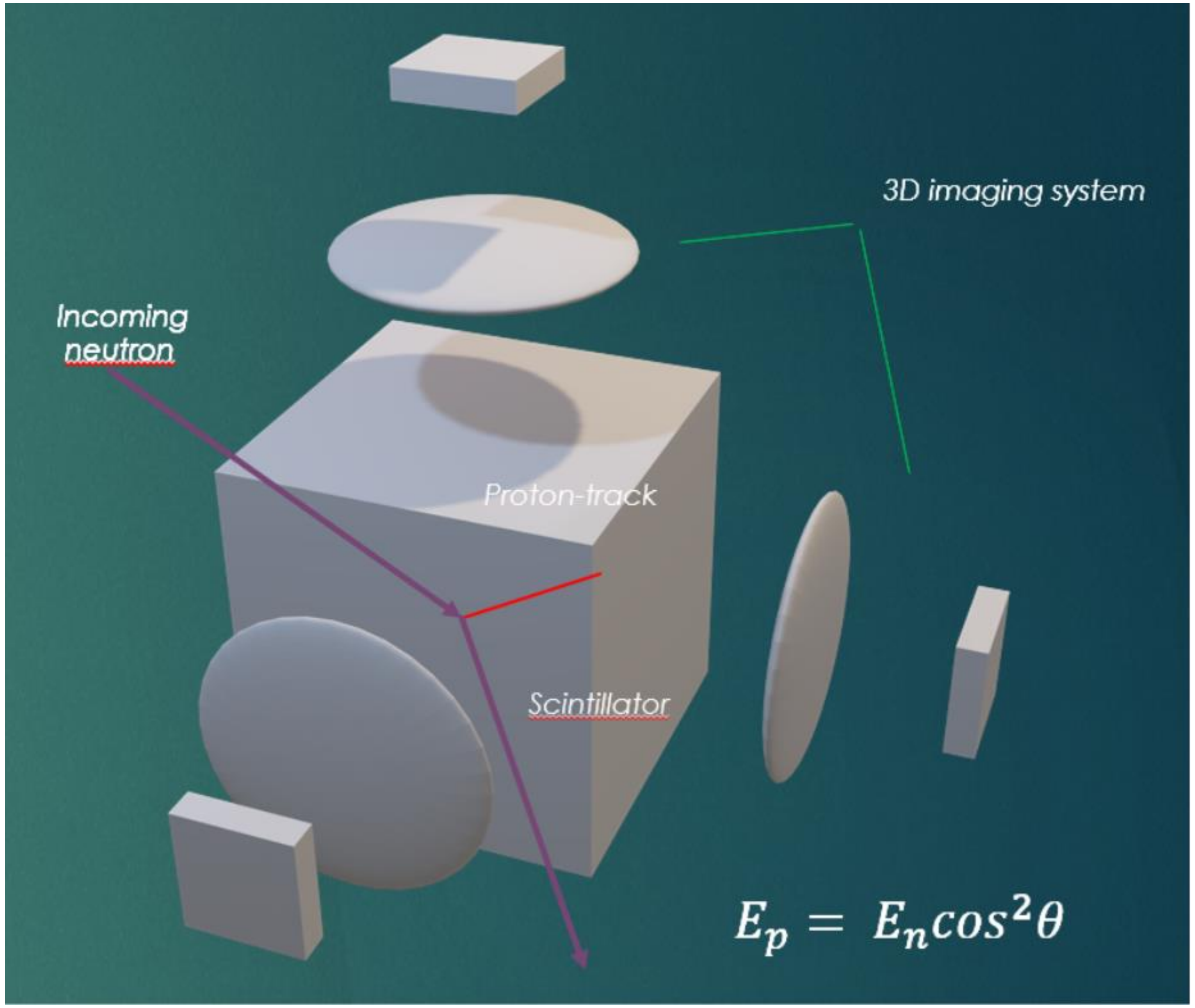


RIPTIDE *the concept extension*

RIPTIDE is a 3D imaging device for high-accuracy Proton-Recoil track reconstruction in a monolithic plastic scintillator

The monolithic arrangement:

- Large boost in detection efficiency
- Several readout configurations according to the application

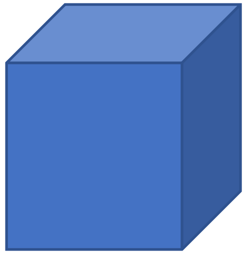


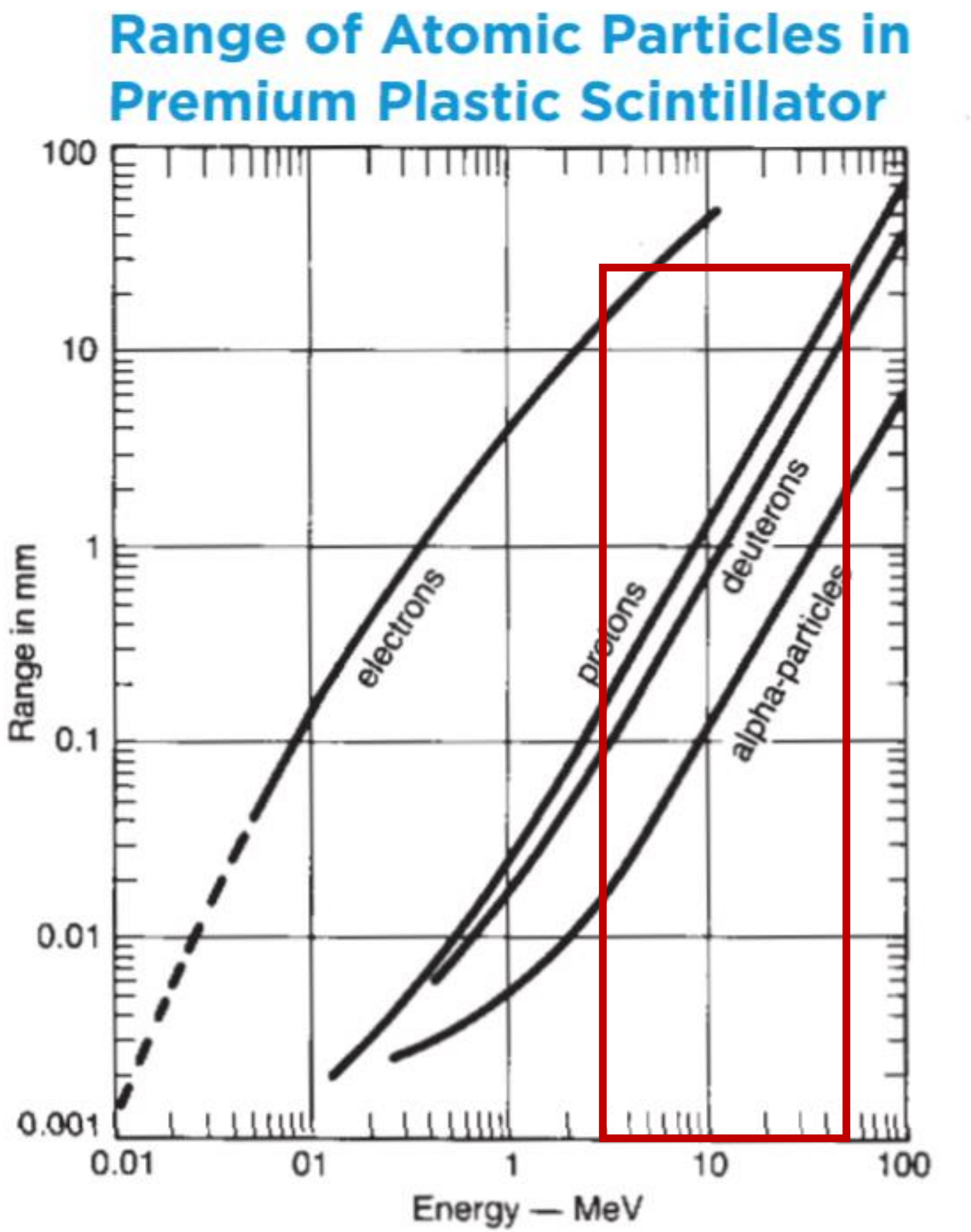
Single *n-p* scattering need the primary vertex

Track discrimination by dE/dx

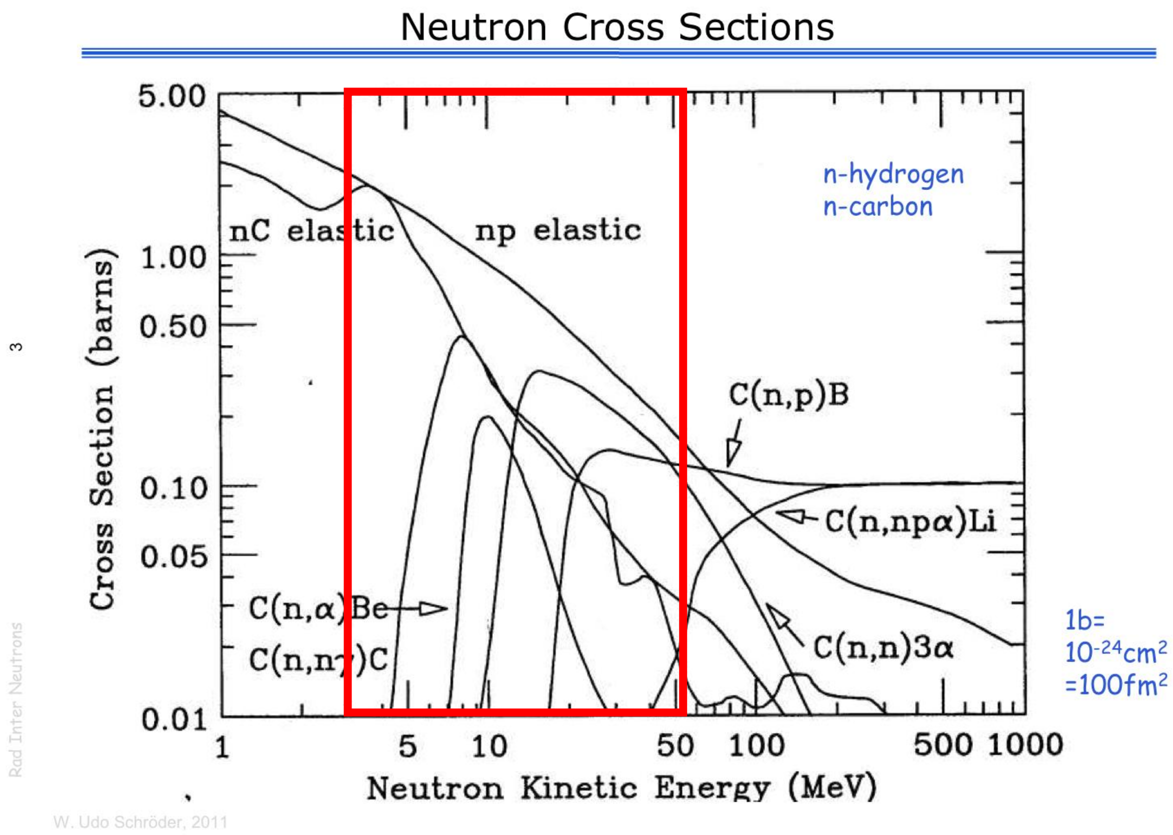
Detection volume *6x6x6* cm^3

Expected neutron enery range 3-50 MeV

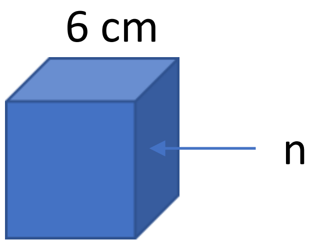




10 photons/keV for plastic scintillators (electrons)



RIPTIDE efficiency I



Multi scattering

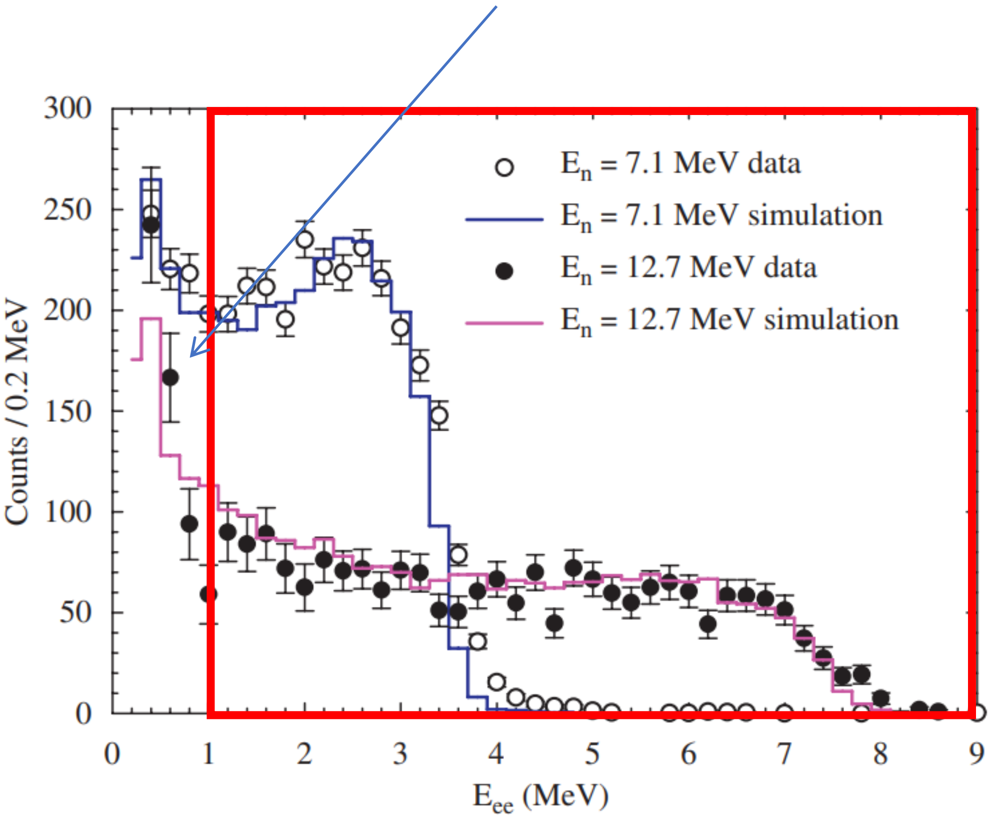


Fig. 11. Experimental and simulated energy (electron equivalent) response of the plastic scintillator to neutrons of energies 7.1 and 12.7 MeV.

Nuclear Instruments and Methods in Physics Research A 598 (2009) 526–533

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Nuclear Instruments and Methods in Physics Research A

journal homepage: www.elsevier.com/locate/nima

A large area plastic scintillator detector array for fast neutron measurements

P.C. Rout [a,b,*], D.R. Chakrabarty [a,b], V.M. Datar [a,b], Suresh Kumar [a], E.T. Mirgule [a], A. Mitra [a], V. Nanal [c], R. Kujur [a]

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[b] Homi Bhabha National Institute, Bhabha Atomic Research Centre, Mumbai 400 085, India
[c] Department of Nuclear and Atomic Physics, Tata Institute of Fundamental Research, Mumbai 400 005, India

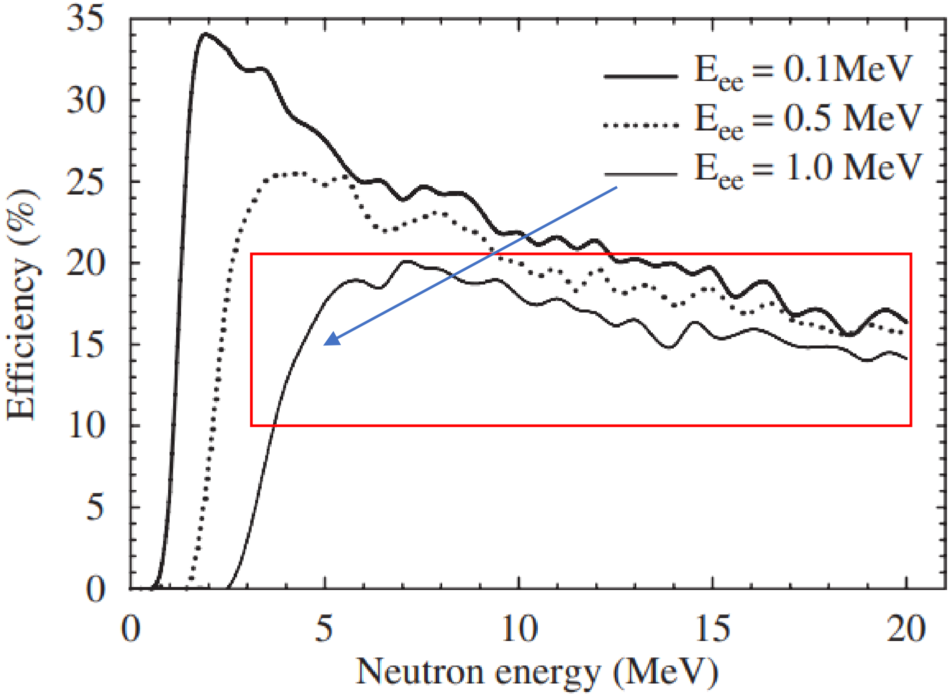
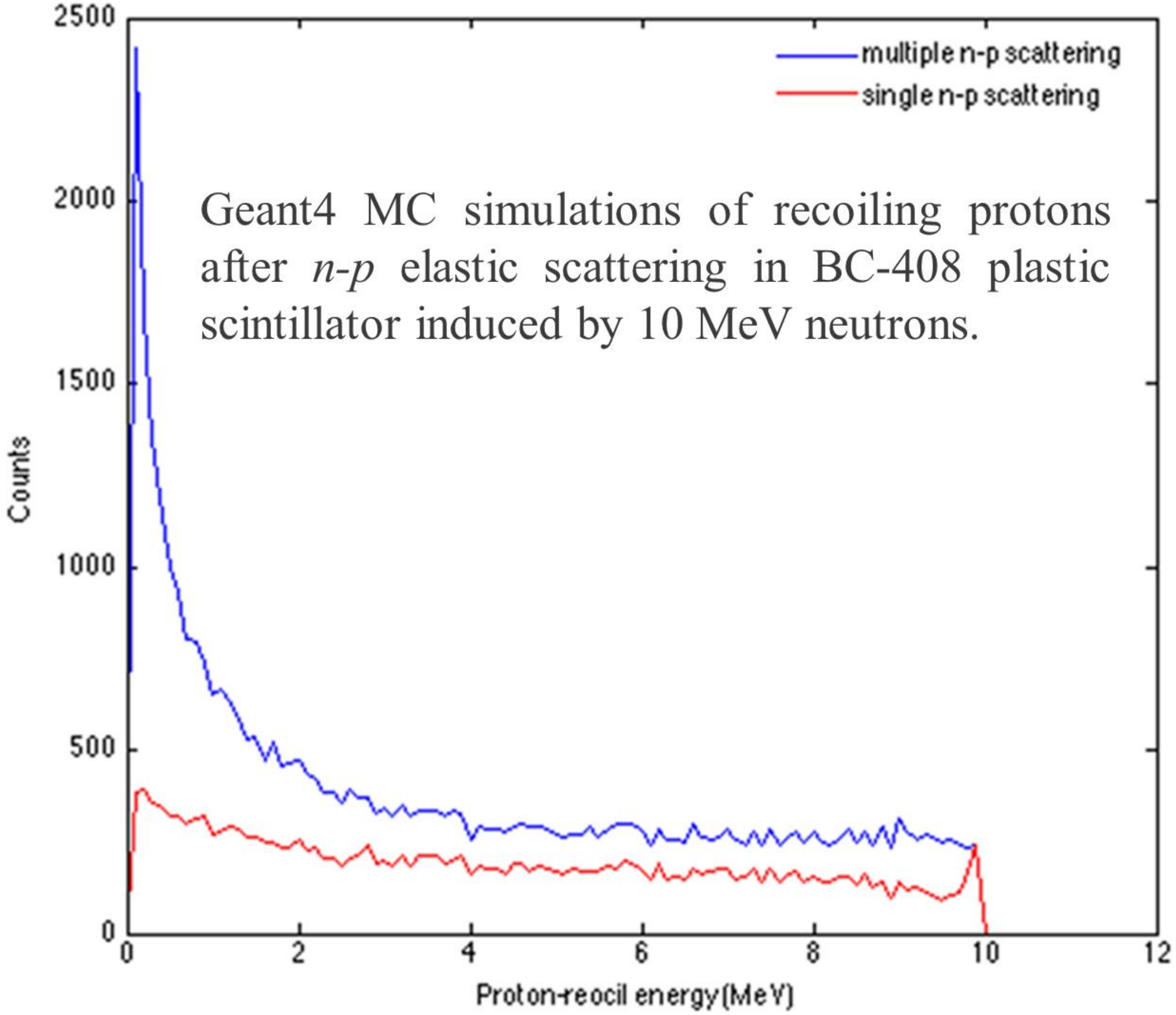


Fig. 12. Simulated neutron efficiency of a plastic bar for different energy thresholds E_{ee}.

RIPTIDE efficiency II

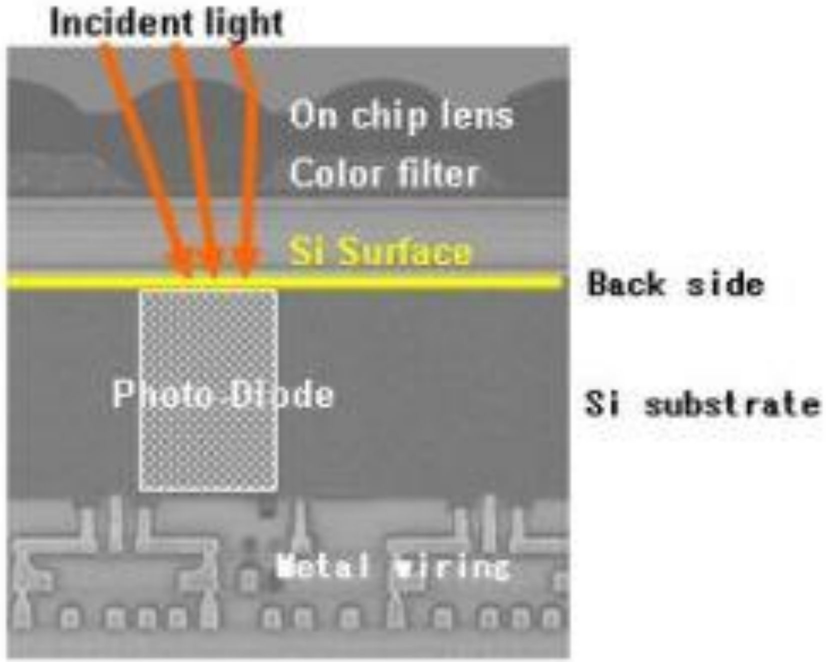
Geant4 Simulations

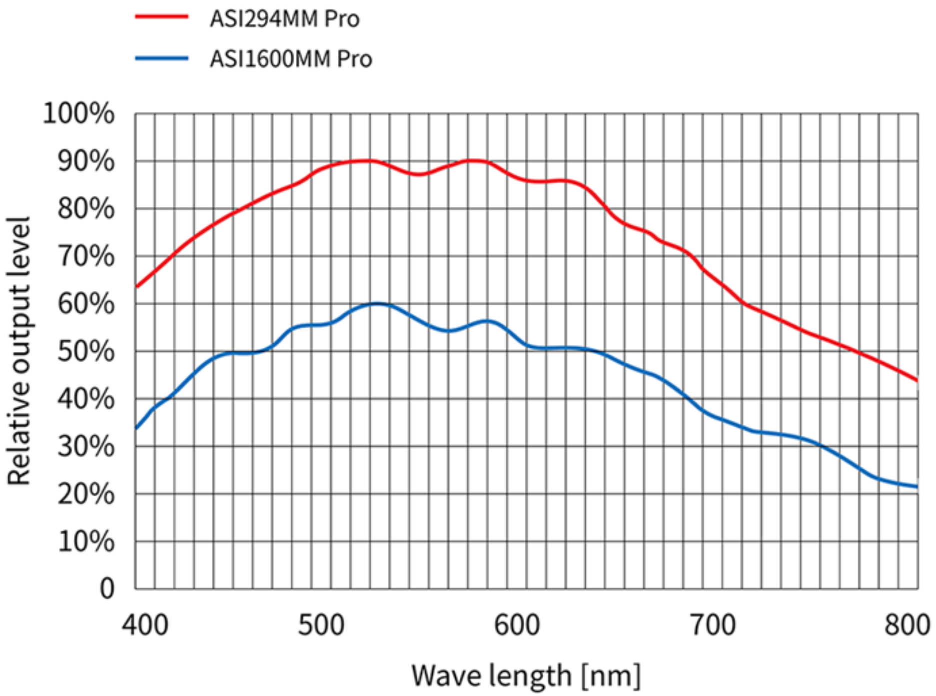
an efficiency of 10-20% can be achieved in the 5 < E <20 MeV neutron energy-range



Detector readout I

Back Illuminated, high-eff. low-noise CMOS devices
(diag. size from 1/3'' to full-frame)
large pixel size (5x5 - 50x50 μm^2)

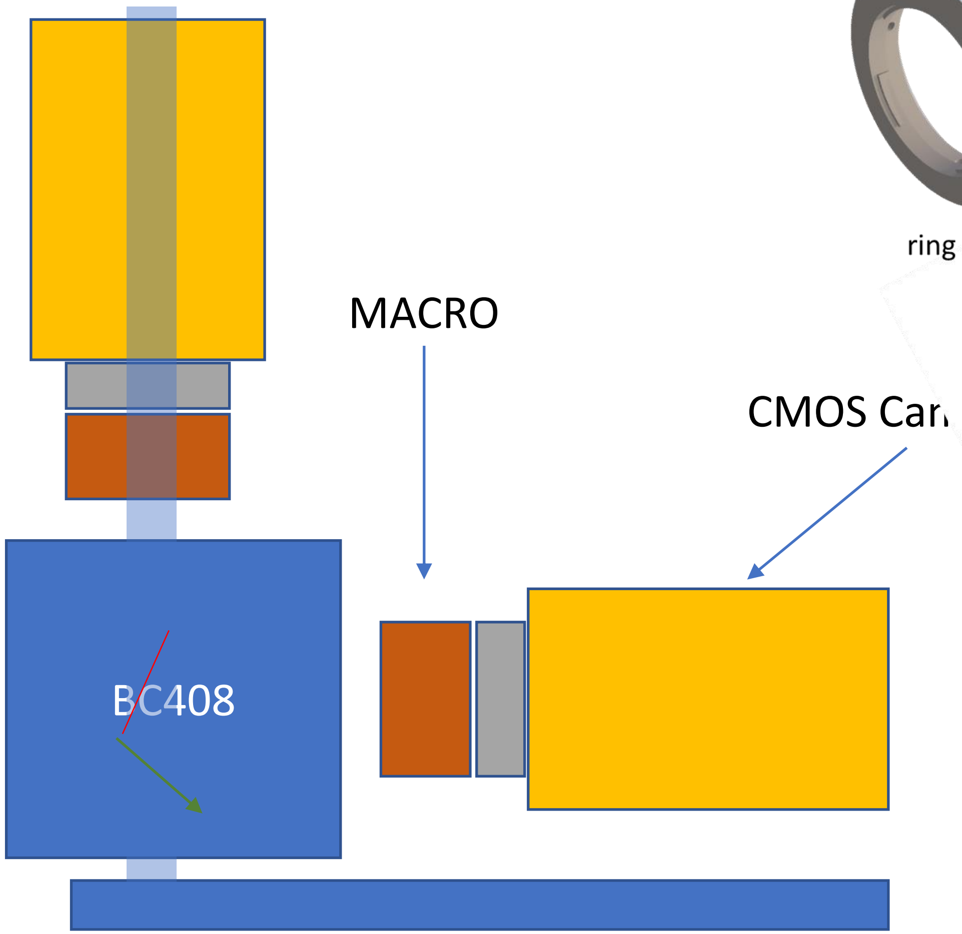




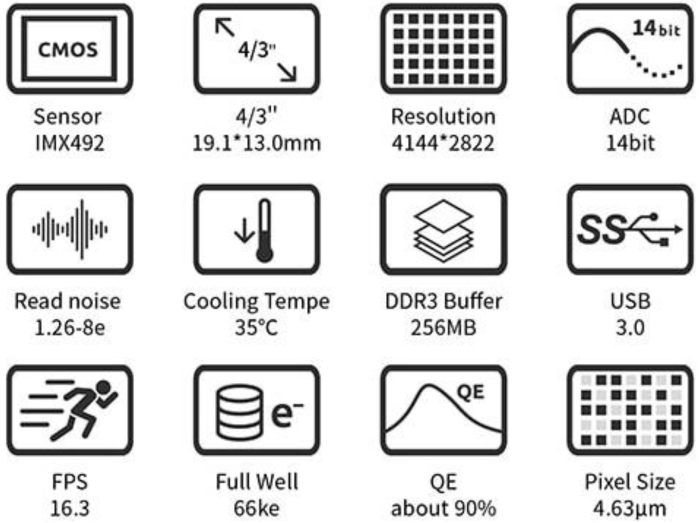
INFN-CT
Sensors & optics

RIPTIDE CMOS track imaging (test setup on 2022/23)

Camera-MACRO lenses X 2 are now available at INFN-CT



CMOS and ***optical coupling***

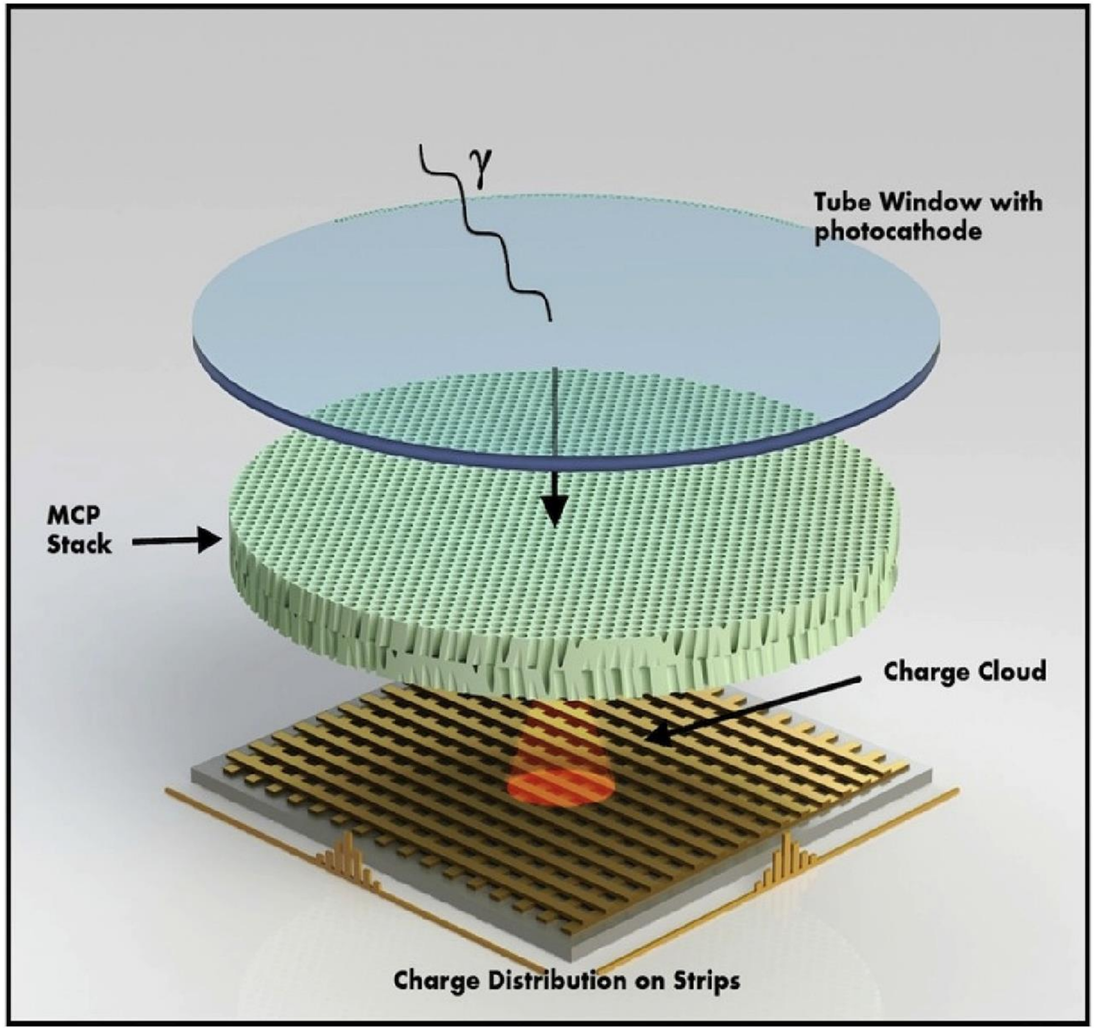


Detector readout II

High conversion efficiency photocathode coupled to MCP (single and chevron setup) with pixel sensors such as TIMEPIX or MIMOSIS

MCP-Timepix combines suitable timing and space resolution

A.S. Tremsin, J.V. Vallerga, Radiat. Meas. 130(2020)106228



INFN-Bo Sensors & Data readout (FPGA)

TIMEPIX

		Timepix3	Timepix4
Technology		IBM 130nm	TSMC 65nm
Pixel Size		55 x 55 µm	≤ 55 x 55 µm
Pixel arrangement		3-side buttable 256 x 256	4-side buttable 256 x 256 or bigger
Operating Modes	Data driven	PC (10-bit) and TOT (14-bit)	CRW: PC and iTOT (12...16-bit)
	Frame based	TOT and TOA	
Zero-Suppressed Readout	Data driven	< 80 MHits/s	< 500 MHits/s
	Frame based	YES	YES
TOT energy resolution		< 2KeV	**< 1Kev**
Time resolution		1.56ns	**~200ps**
Readout bandwidth		5.12Gb (8x SLVS@640 Gbps)	20.48 Gbps (4x 5.12 Gbps)
Front-end		"with" Volcano	No volcano → Dynamic gain But supply only 1.2V